**JIGS & FIXTURES**: Principles of design of jigs and fixtures and uses, classification of jigs & fixtures, principles of location and clamping, types of clamping & work holding devices, typical examples of jigs and fixtures.

Introduction The successful running of any mass production depends upon the interchangeability to facilitate easy assembly and reduction of unit cost. Mass production methods demand a fast and easy method of positioning work for accurate operations on it. Jigs and fixtures are production tools used to accurately manufacture duplicate and interchangeable parts. Jigs and fixtures are specially designed so that large numbers of components can be machined or assembled identically, and to ensure interchangeability of components.

JIGS It is a work holding device that holds, supports and locates the workpiece and guides the cutting tool for a specific operation. Jigs are usually fitted with hardened steel bushings for guiding or other cutting tools. a jig is a type of tool used to control the location and/or motion of another tool. A jig's primary purpose is to provide repeatability, accuracy, and interchangeability in the manufacturing of products. A device that does both functions (holding the work and guiding a tool) is called a jig. An example of a jig is when a key is duplicated; the original is used as a jig so the new key can have the same path as the old one.

FIXTURES It is a work holding device that holds, supports and locates the workpiece for a specific operation but does not guide the cutting tool. It provides only a reference surface or a device. What makes a fixture unique is that each one is built to fit a particular part or shape. The main purpose of a fixture is to locate and in some cases hold a workpiece during either a machining operation or some other industrial process. A jig differs from a fixture in that a it guides the tool to its correct position in addition to locating and supporting the workpiece. Examples: Vises, chucks

How do jigs and fixtures differ.

|  |  |
| --- | --- |
| JIGS | FIXTURES |
| 1. It is a work holding device that holds, supports and locates the workpiece and guides the cutting tool for a specific operation | 1. It is a work holding device that holds, supports and locates the workpiece for a specific operation but does not guide the cutting tool |
| 2. Jigs are not clamped to the drill press table unless large diameters to be drilled and there is a necessity to move the jig to bring one each bush directly under the drill. | 2. Fixtures should be securely clamped to the table of the machine upon which the work is done. |
| 3. The jigs are special tools particularly in drilling, reaming, tapping and boring operation. | 3. Fixtures are specific tools used particularly in milling machine, shapers and slotting machine. |
| 4. Gauge blocks are not necessary. | 4. Gauge blocks may be provided for effective handling. |
| 5. Lighter in construction. | 5. Heavier in construction. |

Advantages of Jigs and Fixtures PRODUCTIVITY: Jigs and fixtures increases the productivity by eliminating the individual marking, positioning and frequent checking. The operation time is also reduced due to increase in speed, feed and depth of cut because of high clamping rigidity. INTERCHANGEABILITY AND QUALITY: Jigs and fixtures facilitate the production of articles in large quantities with high degree of accuracy, uniform quality and interchangeability at a competitive cost .

Fundamental principles of Jigs and Fixtures design LOCATING POINTS: Good facilities should be provided for locating the work. The article to be machined must be easily inserted and quickly taken out from the jig so that no time is wasted in placing the workpiece in position to perform operations. The position of workpiece should be accurate with respect to tool guiding in the jig or setting elements in fixture. FOOL PROOF: The design of jigs and fixtures should be such that it would not permit the workpiece or the tool to inserted in any position other than the correct one. • REDUCTION OF IDLE TIME: Design of Jigs and Fixtures should be such that the process, loading, clamping and unloading time of the workpiece takes minimum as far as possible. • WEIGHT OF JIGS AND FIXTURES: It should be easy to handle, smaller in size and low cost in regard to amount of material used without sacrificing rigidity and stiffness. • JIGS PROVIDED WITH FEET: Jigs sometimes are provided with feet so that it can be placed on the table of the machine. • MATERIALS FOR JIGS AND FIXTURES: Usually made of hardened materials to avoid frequent damage and to resist wear. ExampleMS, Cast iron, Diesteel, CS, HSS. • CLAMPING DEVICE: It should be as simple as possible without sacrificing effectiveness. The strength of clamp should be such that not only to hold the workpiece firmly in place but also to take the strain of the cutting tool without springing when designing the jigs and fixtures.

Essential features of Jigs and Fixtures Reduction of idle time – Should enable easy clamping and¬ unloading such that idle time is minimum Cleanliness of machining process – Design must be such that not¬ much time is wasted in cleaning of scarfs, burrs, chips etc. Replaceable part or standardization – The locating and supporting¬ surfaces as far as possible should be replaceable, should be standardized so that their interchangeable manufacture is possible Provision for coolant – Provision should be there so that the tool is¬ cooled and the swarfs and chips are washed away Hardened surfaces – All locating and supporting surfaces¬ should be hardened materials as far as conditions permit so that they are not quickly worn out and accuracy is retained for a long time Inserts and pads – Should always be riveted to those faces of¬ the clamps which will come in contact with finished surfaces of the workpiece so that they are not spoilt Fool-proofing – Pins and other devices of simple nature¬ incorporated in such a position that they will always spoil the placement of the component or hinder the fitting of the cutting tool until the latter are in correct pos Economic soundness – Equipment should be economically¬ sound, cost of design and manufacture should be in proportion to the quantity and price of producer Easy manipulation – It should be as light in weight as possible¬ and easy to handle so that workman is not subjected to fatigue, should be provided with adequate lift aids Initial location – Should be ensured that workpiece is not¬ located on more than 3 points in anyone plane test to avoid rocking, spring loading should be done Position of clamps – Clamping should occur directly above¬ the points supporting the workpiece to avoid distortion and springing Clearance – Sufficient amount of clearance should be provided¬ around the work so that operator’s hands can easily enter the body for placing the workpiece and any variations of work can be accommodated Ejecting devices – Proper ejecting devices should be incorporated¬ in the body to push the workpiece out after operation Rigidity and stability – It should remain perfectly rigid and stable¬ during operation. Provision should be made for proper positioning and rigidly holding the jigs and fixtures Safety – The design should assure perfect safety of the operator¬ General rules for designing Compare the cost of production of work with present tools with the expected cost of production, using the tool to be made and see that the cost of buildings is not in excess of expected gain. Decide upon locating points and outline clamping arrangement Make all clamping and binding devices as quick acting as possible Make the jig fool proof Make some locating points adjustable Avoid complicated clamping arrangements Round all corners Provide handles wherever these will make handling easy Provide abundant clearance Provide holes on escapes for chips Locate clamps so that they will be in best position to resist the pressure of the cutting tool when at work Place all clamps as nearly as possible opposite some bearing point of the work to avoid springing action Before using in the shop, test all jigs as soon as made MATERIALS USED Jigs and Fixtures are made of variety of materials, some of¬ which can be hardened to resist wear. Materials generally used:¬ High speed Steel: Cutting tools like drills, reamers and milling¬ cutters. Die steels: Used for press tools, contain 1% carbon, 0.5 to 1%¬ tungsten and less quantities of silicon and manganese. Carbon steels: Used for standard cutting tools.¬ Collet steels: Spring steels containing 1% carbon, 0.5%¬ manganese and less of silicon. 5. Non shrinking tool steels: High carbon or high chromium Very little distortion during heat treatment. Used widely for fine, intricate press tools. 6. Nickel chrome steels: Used for gears. 7. High tensile steels: Used for fasteners like high tensile screws 8. Mild steel: Used in most part of Jigs and Fixtures Cheapest material Contains less than 0.3% carbon 9. Cast Iron: Used for odd shapes to some machining and laborious fabrication CI usage requires a pattern for casting Contains more than 2% carbon Has self lubricating properties Can withstand vibrations and suitable for base 10. Nylon and Fiber: Used for soft lining for clamps to damage to workpiece due to clamping pressure 11. Phospher bronze: used for nuts as have high tensile strength Used for nuts of the lead screw Factors to be considered for design of Jigs and Fixtures 1. Component- Design to be studied carefully Ensure work is performed in a proper sequence Maximum operations should be performed on a machine in single setting 2. Capacity of the machine- Careful consideration to be performed on type and capacity of machine. 3. Production requirements- Design to be made on basis of actual production requirements. Then comes decision on manual and automatic tooling arrangements. 4. Location- • Location should ensure equal distribution of forces throughout all sequence of operation. • Location should be hard resistant, wear resistant and high degree of accuracy. • Movement of workpiece should be restricted. • Should be fool proofed to avoid improper locations of the workpiece. • Should facilitate easy and quick loading of workpiece. • Redundant locators should be avoided. • Sharp corners must be avoided. • At least one datum surface should be establised. 5. Loading and Unloading arrangements- There should be adequate clearance for loading and unloading. Hence process becomes quick and easy. Size variation must be accepted. It should be hardened material and non sticky. 6. Clamping arrangements- Quick acting clamps must be used as far as possible. The clamping should not cause any deformation to the workpiece It should always be arranged directly above points supporting the work. Power driven clamps are favoured as they are quick acting, controllable, reliable and operated without causing any fatigue to the operators. Features of clamps: Clamping pressure should be low Should not cause distortion Simple and fool proof Movement of clamp should be minimum Case hardened to prevent wear Sufficiently robust to avoid bending 7. Clearance between Jig and Component- To accommodate various sizes if work Chips to pass out of the opening between them 8. Ejectors- To remove work from close fitting locators. Speeds up unloading of the part from the tool and hence production rate. 9. Base and Body construction- Methods used: Machining, Forging and machining, Casting, Fabricating, Welding. 10. Tool guiding and cutter setting- By adjusting the machine or using cutter setting block, the cutter is set relative to the work in a fixture. The drill bushes fitted on jig plates guides the tools. 11. Rigidity and vibration- Must possess enough rigidity and robustness. Should not vibrate as it may lead to unwanted movement of workpiece and tools. 12. Safety- Operation should be assured full safety. 13. Cost- Should be simple as possible. Cost incurred should be optimum

**Numerical Control (NC) Machine Tools**

Numerical Control (NC) refers to the method of controlling the manufacturing operation by means of directly inserted coded numerical instructions into the machine tool. It is important to realize that NC is not a machining method, rather, it is a concept of machine control. Although the most popular applications of NC are in machining, NC can be applied to many other operations, including welding, sheet metalworking, riveting, etc.

The major advantages of NC over conventional methods of machine control are as follows:

Higher precision

Machining of complex three-dimensional shapes

Better quality

Higher productivity

Multi-operational machining

Low operator qualification

**Types of NC systems**

Machine controls are divided into three groups,

Traditional numerical control (NC);

Computer numerical control (CNC);

Distributed numerical control (DNC).

The original numerical control machines were referred to as NC machine tool. They have

“hardwired” control, whereby control is accomplished through the use of punched paper (or plastic) tapes or cards. Tapes tend to wear, and become dirty, thus causing misreadings. Many other problems arise from the use of NC tapes, for example the need to manual reload the NC tapes for each new part and the lack of program editing abilities, which increases the lead time. The end of NC tapes was the result of two competing developments, CNC and DNC.

**Types of NC systems**

Machine controls are divided into three groups,

1.Traditional numerical control (NC);

2.Computer numerical control (CNC);

3.Distributed numerical control (DNC).

The original numerical control machines were referred to as NC machine tool. They have

“hardwired” control, whereby control is accomplished through the use of punched paper (or plastic) tapes or cards. Tapes tend to wear, and become dirty, thus causing misreadings. Many other problems arise from the use of NC tapes, for example the need to manual reload the NC tapes for each new part and the lack of program editing abilities, which increases the lead time. The end of NC tapes was the result of two competing developments, CNC and DNC.

CNC refers to a system that has a local computer to store all required numerical data. While CNC was used to enhance tapes for a while, they eventually allowed the use of other storage media, magnetic tapes and hard disks. The advantages of CNC systems include but are not limited to the possibility to store and execute a number of large programs (especially if a three or more dimensional machining of complex shapes is considered), to allow editing of programs, to execute cycles of machining commands, etc.

The development of CNC over many years, along with the development of local area networking, has evolved in the modern concept of DNC. Distributed numerical control is similar to CNC, except a remote computer is used to control a number of machines. An off-site mainframe host computer holds programs for all parts to be produced in the DNC facility. Programs are downloaded from the mainframe computer, and then the local controller feeds instructions to the hardwired NC machine.

The recent developments use a central computer which communicates with local CNC computers (also called Direct Numerical Control)

**Controlled axes**

NC system can be classified on the number of directions of motion they are capable to control simultaneously on a machine tool. Each free body has six degree of freedom, three positive or negative translations along x, y, and z-axis, and three rotations clockwise or counter clockwise about these axes. Commercial NC systems are capable of controlling simultaneously two, two and half, three, four and five degrees of freedom, or axes. The NC systems which control three linear translations (3-axis systems), or three linear translations and one rotation of the worktable (4-axis systems) are the most common.

Although the directions of axes for a particular machine tool are generally agreed as shown in the figure, the coordinate system origin is individual for each part to be machined and has to be decided in the very beginning of the process of CNC part programming.

**Point-to-point vs. continuous systems**

The two major types of NC systems are (see the figure):

Point-to-point (PTP) system, and Contouring system.

PTP is a NC system, which controls only the position of the components. In this system, the path of the component motion relative to the workpiece is not controlled. The travelling between different positions is performed at the traverse speed allowable for the machine tool and following the shortest way.

Contouring NC systems are capable of controlling not only the positions but also the component motion, i.e., the travelling velocity and the programmed path between the desired positions.

**Computer numerical control (CNC)**

Numerical control (NC) is the automation of machine tools that are operated by precisely programmed commands encoded on a storage medium, as opposed to controlled manually via hand wheels or levers, or mechanically automated via cams alone. Most NC today is computer numerical control (CNC), in which computers play an integral part of the control.

In modern CNC systems, end-to-end component design is highly automated using computer-aided design (CAD) and computer-aided manufacturing (CAM) programs. The programs produce a computer file that is interpreted to extract the commands needed to operate a particular machine via a post processor, and then loaded into the CNC machines for production. Since any particular component might require the use of a number of different tools – drills, saws, etc., modern machines often combine multiple tools into a single "cell". In other installations, a number of different machines are used with an external controller and human or robotic operators that move the component from machine to machine. In either case, the series of steps needed to produce any part is highly automated and produces a part that closely matches the original CAD design.



The first NC machines were built in the 1940s and 1950s, based on existing tools that were modified with motors that moved the controls to follow points fed into the system on punched tape. These early servomechanisms were rapidly augmented with analog and digital computers, creating the modern CNC machine tools that have revolutionized the machining processes.

Modern CNC mills differ little in concept from the original model built at MIT in 1952. Mills typically consist of a table that moves in the X and Y axes, and a tool spindle that moves in the Z (depth). The position of the tool is driven by motors through a series of step-down gears in order to provide highly accurate movements, or in modern designs, direct-drive stepper motor or servo motors. Open-loop control works as long as the forces are kept small enough and speeds are not too great. On commercial metalworking machines closed loop controls are standard and required in order to provide the accuracy, speed, and repeatability demanded.

As the controller hardware evolved, the mills themselves also evolved. One change has been to enclose the entire mechanism in a large box as a safety measure, often with additional safety interlocks to ensure the operator is far enough from the working piece for safe operation. Most new CNC systems built today are completely electronically controlled.

CNC-like systems are now used for any process that can be described as a series of movements and operations. These include laser cutting, welding, friction stir welding, ultrasonic welding, flame and plasma cutting, bending, spinning, hole-punching, pinning, gluing, fabric cutting, sewing, tape and fiber placement, routing, picking and placing (PnP), and sawing.

**Mills**

CNC mills use computer controls to cut different materials. They are able to translate programs consisting of specific number and letters to move the spindle to various locations and depths. Many use G-code, which is a standardized programming language that many CNC machines understand, while others use proprietary languages created by their manufacturers. These proprietary languages while often simpler than G-code are not transferable to other machines.

Lathes

Lathes are machines that cut spinning pieces of metal. CNC lathes are able to make fast, precision cuts using indexable tools and drills with complicated programs for parts that normally cannot be cut on manual lathes. These machines often include 12 tool holders and coolant pumps to cut down on tool wear. CNC lathes have similar control specifications to CNC mills and can often read G-code as well as the manufacturer's proprietary programming language.

**Plasma cutters**



CNC plasma cutting

Plasma cutting involves cutting a material using a plasma torch. It is commonly used to cut steel and other metals, but can be used on a variety of materials. In this process, gas (such as compressed air) is blown at high speed out of a nozzle; at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of that gas toplasma. The plasma is sufficiently hot to melt the material being cut and moves sufficiently fast to blow molten metal away from the cut.

**Electric discharge machining**

Electric discharge machining (EDM), sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking, or wire erosion, is a manufacturing process in which a desired shape is obtained using electrical discharges (sparks). Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric fluid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the "tool" or "electrode," while the other is called the workpiece-electrode, or "workpiece."

When the distance between the two electrodes is reduced, the intensity of the electric field in the space between the electrodes becomes greater than the strength of the dielectric (at least in some point(s)), which breaks, allowing current to flow between the two electrodes. This phenomenon is the same as the breakdown of a capacitor. As a result, material is removed from both the electrodes. Once the current flow stops (or it is stopped – depending on the type of generator), new liquid dielectric is usually conveyed into the inter-electrode volume enabling the solid particles (debris) to be carried away and the insulating proprieties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as flushing. Also, after a current flow, a difference of potential between the two electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur.

**Wire EDM**

Also known as wire cutting EDM, wire burning EDM, or traveling wire EDM, this process uses spark erosion to machine or remove material with a traveling wire electrode from any electrically conductive material. The wire electrode usually consists of brass or zinc-coated brass material.

**Sinker EDM**

Sinker EDM, also called cavity type EDM or volume EDM, consists of an electrode and workpiece submerged in an insulating liquid—often oil but sometimes other dielectric fluids. The electrode and workpiece are connected to a suitable power supply, which generates an

electrical potential between the two parts. As the electrode approaches the workpiece, dielectric breakdown occurs in the fluid forming a plasma channel) and a small spark jumps.

**Water jet cutters**

A water jet cutter, also known as a waterjet, is a tool capable of slicing into metal or other materials (such as granite) by using a jet of water at high velocity and pressure, or a mixture of water and an abrasive substance, such as sand. It is often used during fabrication or manufacture of parts for machinery and other devices. Waterjet is the preferred method when the materials being cut are sensitive to the high temperatures generated by other methods. It has found applications in a diverse number of industries from mining to aerospace where it is used for operations such as cutting, shaping, carving, and reaming.

Other CNC tools:  Many other tools have CNC variants, including:

       Drills



       EDMs



       Embroidery machines



       Lathes



       Milling machines



       Wood routers



       Sheet metal works (Turret punch)



       Wire bending machines



       Hot-wire foam cutters



       Plasma cutters



       Water jet cutters



       Laser cutting



       Oxy-fuel



       Surface grinders



       Cylindrical grinders



       3D Printing



       Induction hardening machines



       submerged welding



       knife cutting



       glass cutting

**Programming Fundamentals CNC**

**Fanuc G-Code List (Lathe)**

G code                  Description

G00   Rapid traverse

G01   Linear interpolation

G02   Circular interpolation CW

G03   Circular interpolation CCW

G04   Dwell

G09   Exact stop

G10   Programmable data input

G20   Input in inch

G21   Input in mm

G22   Stored stroke check function on

G23   Stored stroke check function off

G27   Reference position return check

G28   Return to reference position

G32   Thread cutting

G40   Tool nose radius compensation cancel

G41   Tool nose radius compensation left

G42   Tool nose radius compensation right

G70   Finish machining cycle

G71   Turning cycle

G72   Facing cycle

G73   Pattern repeating cycle

G74   Peck drilling cycle

G75   Grooving cycle

G76   Threading cycle

G92   Coordinate system setting or max. spindle speed setting

G94   Feed Per Minute

G95   Feed Per Revolution

G96   Constant surface speed control

G97   Constant surface speed control cancel

**Fanuc G-Code List (Mill)**

**G code                 Description**

          G00            Rapid traverse

          G01            Linear interpolation

          G02            Circular interpolation CW

          G03            Circular interpolation CCW

          G04            Dwell

          G17            X Y plane selection

          G18            Z X plane selection

          G19            Y Z plane selection

          G28            Return to reference position

G30   2nd, 3rd and 4th reference position return

G40   Cutter compensation cancel

G41   Cutter compensation left

G42   Cutter compensation right

G43   Tool length compensation + direction

G44   Tool length compensation – direction

G49   Tool length compensation cancel

G53   Machine coordinate system selection

G54   Workpiece coordinate system 1 selection

G55   Workpiece coordinate system 2 selection

G56   Workpiece coordinate system 3 selection

G57   Workpiece coordinate system 4 selection

G58   Workpiece coordinate system 5 selection

G59   Workpiece coordinate system 6 selection

G68   Coordinate rotation

G69   Coordinate rotation cancel

G73   Peck drilling cycle

G74   Left-spiral cutting circle

G76   Fine boring cycle

G80   Canned cycle cancel

G81   Drilling cycle, spot boring cycle

G82   Drilling cycle or counter boring cycle

G83   Peck drilling cycle

G84   Tapping cycle

G85   Boring cycle

G86   Boring cycle

G87   Back boring cycle

G88   Boring cycle

G89   Boring cycle

G90   Absolute command

G91   Increment command

G92 Setting for work coordinate system or clamp at maximum spindle speed

G98 Return to initial point in canned cycle

G99   Return to R point in canned cycle

**Fanuc M-Code List (Lathe)**

          M code                                    Description

          M00                               Program stop

          M01                               Optional program stop

          M02                               End of program

          M03                               Spindle start forward CW

          M04                               Spindle start reverse CCW

          M05                               Spindle stop

          M08                               Coolant on

          M09                               Coolant off

          M29                               Rigid tap mode

          M30                               End of program reset

          M40                               Spindle gear at middle

          M41                               Low Gear Select

          M42                               High Gear Select

 M68                               Hydraulic chuck close

          M69                               Hydraulic chuck open

          M78                               Tailstock advancing

          M79                               Tailstock reversing

          M94                               Mirrorimage cancel

          M95                               Mirrorimage of X axis

          M98                               Subprogram call

          M99                               End of subprogram

**Fanuc M-Code List (Mill)**

M code                 Description

          M00            Program stop

          M01            Optional program stop

          M02            End of program

          M03            Spindle start forward CW

          M04            Spindle start reverse CCW

          M05            Spindle stop

          M06            Tool change

          M07            Coolant ON – Mist coolant/Coolant thru spindle

          M08            Coolant ON – Flood coolant

M09  Coolant OFF

M19  Spindle orientation

M28  Return to origin

M29  Rigid tap

M30  End of program (Reset)

M41  Low gear select

M42  High gear select

M94  Cancel mirrorimage

M95  Mirrorimage of X axis

M96  Mirrorimage of Y axis

M98  Subprogram call

**Manual Part Programming**

**Lathe**

G02 G03 G Code Circular Interpolation

G02 G Code Clock wise Circular Interpolation.

G03 G Code Counter Clock wise Circular Interpolation.

There are multiple articles/cnc program examples about G code circular interpolation, here is the list of few articles so that cnc machinists can easily navigate through different cnc programming articles.

**G02 G03 G Code Example CNC Programs (G code Arc Examples)**o CNC Circular Interpolation Tutorial G02 G03

o  Fanuc CNC Lathe Programming Example

o CNC Programming Example G Code G02 Circular Interpolation Clockwise o Fanuc G20 Measuring in Inches with CNC Program Example

o  CNC Arc Programming Exercise

o CNC Programming for Beginners a CNC Programming Example o CNC Lathe Programming Example

Here is a new CNC programming examples which shows the use of G02 G03 G code circular interpolation.

**G02 G03 G Code Example Program**



G02 G03 G Code Circular Interpolation Example Program

N20 G50 S2000 T0300

G96 S200 M03

G42 G00 X35.0 Z5.0 T0303 M08

G01 Z-20.0 F0.2

G02 X67.0 Z-36.0 R16.0

G01 X68.0 :

G03 X100.0 Z-52.0 R16.0

G01 Z-82.0

G40 G00 X200.0 Z200.0 M09 T0300

M30

**G Code G02 G03 I & K Example Program**

G02 G03 G Code Circular Interpolation can be programmed in two ways,

G02 X... Z... R...

G02 X... Z... I... K...

The below is the same cnc program but this version uses I & K with G02 G03 G code.

N20 G50 S2000 T0300

G96 S200 M03

G42 G00 X35.0 Z5.0 T0303 M08

G01 Z-20.0 F0.2

G02 X67.0 Z-36.0 I16.0 K0

G01 X68.0 :

G03 X100.0 Z-52.0 I0 K-16.0

G01 Z-82.0

G40 G00 X200.0 Z200.0 M09 T0300

M30

**G20 Turning Cycle Format for Straight Turning**

G20 X… Z… F…

or

G20 U… W… F…

X – Diameter to be cut (absolute).

Z – End point in z-axis (absolute).

F – Feed-rate.

U – Diameter to be cut (incremental).

W – End point in z-axis (incremental).

 G20 Turning Cycle – CNC Lathe Fanuc 21 TB

**G20 Turning Cycle Format for Taper Turning**

G20 X… Z… R… F…

or

G20 U… W… R… F…

X – Diameter to be cut (absolute).

Z – End point in z-axis (absolute).

R – Incremental taper dimension in X with direction (+/-)

F – Feed-rate.

U – Diameter to be cut (incremental).

W – End point in z-axis (incremental).

As cnc machinists can use X or U value for the contour value, same way Z or W can be used or you can even mix both absolute (X, Z) and incremental (U, W) values.

**G20 Turning Cycle Example CNC Program Code**

G96 S200 M03

G00 X56.0 Z2.0

G20 X51.0 W-20.0 F0.25

X46.0

X41.0

X36.0

X31.0

X30.0

G00 X100 Z100

M30

**CNC Program Code Explanation**

As you can see in the above cnc program code, Tool is at X56 Z2 point,

First cut is made at X51 and tool travels W-20 in Z-axis. Second cut is made at X46

Third cut is made at X41

…

Last cut is made at X30

**G20 Turning Cycle Function**

 As if you study the above cnc program code you will notice that, 1 – with G20 both absolute (X51.0) and incremental (W-20.0) values are used to make cuts. 2 – If above code also shows a very powerful functionality of G20 turning cycle which is that a cnc machinist can control depth-of-cut of every pass of G20 turning cycle which is impossible to achieve with other Turning Canned Cycle like G71 Rough Turning Cycle. So you will notice first five-cuts are of 5mm deep but the last one is just 1mm deep.

**Cancellation of G20 Turning Cycle**

G20 turning cycle is a modal G-code.

“Modal” G-code meaning that they stay in effect until they are cancelled or replaced by a contradictory G code.

It means G20 turning cycle remains active until another motion command is given like G00, G01 etc. As in above cnc program example G20 G code is cancelled with G00 G code.

Milling

**Programming**

G72.1 P... L... X... Y... R...

**Parameters**

**Parameter Description**

P Subprogram number

L Number of times the operation is repeated

X Center of rotation on the X axis

Y Center of rotation on Y axis

R Angular  displacement  (a  positive  value  indicates a  counter  clockwise angular displacement. Specify an incremental value.)

**G-Code Data**

**Modal/Non-Modal : G-Code Group**

Non-Modal : 00

**Programming Notes**

**Notes**

1.    In the G72.1 block, addresses other than P, L, X, Y and R are ignored.

2.    P, X, Y and R must always be specified.

3.    If L is not specified, the figure is copied once.

4.    The coordinate of the center of rotation is handled as an absolute value even if it is specified in the incremental mode.

5.    Specify an increment in the angular displacement at address R. The angular displacement (degree) for the Nth figure is calculated as follows: Rx(N-1).

**First block of the subprogram**

Always specify a move command in the first block of a subprogram that performs a rotational copy. If the first block contains only the program number such as O00001234; and

does not have a move command, movement may stop at the start point of the figure made by the n-th (n = 1,2, 3, …) copying.

Example of an incorrect program

O00001234 ;

G00 G90 X100.0 Y200.0 ;

;

;

M99 ;

Example of a correct program

O00001000 G00 G90 X100.0 Y200.0 ;

;

;

M99 ;

**Limitation**

Specifying two or more commands to copy a figure

G72.1 cannot be specified more than once in a subprogram for making a rotational copy (If this is attempted, alarmPS0900 will occur).

In a subprogram that specifies rotational copy, however, linear copy (G72.2) can

be specified. Similarly, in a subprogram that specifies linear copy, rotational copy can be specified.

Commands that must not be specified Within a program that performs a rotational copy, the following must not be specified: Command for changing the selected plane (G17 to G19) Command for specifying polar coordinates (G16)

Reference position return command(G28) Axis switching

Coordinate system rotation (G68) scaling (G51)

programmable mirror image (G51.1)

The command for rotational copying can be specified after a command for coordinate system rotation, scaling, or programm able mirror image is executed.

**Single** **block**

Single-block stops are not performed in a block with G721.1 or G72.2.

G72.1 Programming Example



Main program

O1000 ;

N10 G90 G00 X80. Y100. ;                       (P1)

N20 Y50. ;  ( P2)

N30 G01 G17 G42 X43.301             Y25. D01 F100 ;(P3)

N40 G72.1 P1100 L3 X0 Y0  R120. ;

N50 G90 G40 G01 X80. Y50 . ;       (P2)

N60 G00 X80. Y100. ;                     (P1)

N70 M30 ;

O1100 G91 G03 X-18.301 Y18.301 R50. ; (P4)

N100

G01   X-5.   Y50. ;         (P5)

N200 G03   X-40. I-20. ;         (P6)

N300 G01   X-5.   Y-50. ;        (P7)

N400 G03   X-18.301 Y-18.301 R50. ;   (P8)

N500 M99 ;

**Micromachining**

Superfinishing, a metalworking process for producing very fine surface finishes

Various micro electro mechanical systems

Bulk micromachining

Surface micromachining

High-aspect-ratio microstructure technologies

Bulk micromachining is a process used to produce micro machinery or micro electro mechanical systems (MEMS).

Unlike surface micromachining, which uses a succession of thin film deposition and selective etching, bulk micromachining defines structures by selectively etching inside a substrate. Whereas surface micromachining creates structures *on top* of a substrate, bulk micromachining produces structures *inside* a substrate.

Usually, silicon wafers are  used  as  substrates for  bulk  micromachining,  as they  can be anisotropically wet  etched,  forming  highly regular  structures.  Wet  etching typically uses alkaline liquid solvents, such as potassium hydroxide (KOH) or tetramethylammonium hydroxide (TMAH) to dissolve silicon which has been left exposed by the photolithography masking step. These alkali solvents dissolve the silicon in a highly anisotropic way, with some crystallographic orientations dissolving up to 1000 times faster than others. Such an approach is often used with very specific crystallographic orientations in the raw silicon to produce V-shaped grooves. The surface of these grooves can be atomically smooth if the etch is carried out correctly, and the dimensions and angles can be precisely defined.

Bulk micromachining starts with a silicon wafer or other substrates which is selectively etched, using photolithography to transfer a pattern from a mask to the surface. Like surface micromachining, bulk micromachining can be performed with wet or dry etches, although the most common etch in silicon is the anisotropic wet etch. This etch takes advantage of the fact that silicon has a crystal structure, which means its atoms are all arranged periodically in lines and planes. Certain planes have weaker bonds and are more susceptible to etching. The etch results in pits that have angled walls, with the angle being a function of the crystal orientation of the substrate. This type of etching is inexpensive and is generally used in early, low-budget research.

Unlike Bulk micromachining, where a silicon substrate (wafer) is selectively etched to produce structures, surface micromachining builds microstructures by deposition and etching of different structural layers on top of the substrate. Generally polysilicon is commonly used as one of the layers and silicon dioxide is used as a sacrificial layer which is removed or etched out to create the necessary void in the thickness direction. Added layers are generally very thin with their size varying from 2-5 Micro metres. The main advantage of this machining process is the possibility of realizing monolithic microsystems in which the electronic and the mechanical components(functions) are built in on the same substrate. The surface micromachined components are smaller compared to their counterparts, the bulk micromachined ones.

As the structures are built on top of the substrate and not inside it, the substrate's properties are not as important as in bulk micromachining, and the expensive silicon wafers can be replaced by cheaper substrates, such as glass or plastic. The size of the substrates can also be much larger than a silicon wafer, and surface micromachining is used to produce TFTs on large area glass substrates for flat panel displays. This technology can also be used for the manufacture of thin film solar cells, which can be deposited on glass, but also on PET substrates or other non-rigid materials.

HARMST is an acronym for **H**igh **A**spect **R**atio **M**icrostructure **T**echnology that describes fabrication technologies, used to create high-aspect-ratio microstructures with heights between tens of micrometers up to a centimeter and aspect ratios greater than 10:1. Examples include the LIGA fabrication process, advanced silicon etch, and deep reactive ion etching.

**Water Machining**

A water jet cutter, also known as a waterjet or waterjet, is an industrial tool capable of cutting a wide variety of materials using a very high-pressure jet of water, or a mixture of water and an abrasive substance. The term abrasive jet refers specifically to the use of a mixture of water and abrasive to cut hard materials such as metal or granite, while the terms pure waterjet and water-only cutting refer to waterjet cutting without the use of added abrasives, often used for softer materials such as wood or rubber. Waterjet cutting is often used during fabrication of machine parts. It is the preferred method when the materials being cut are sensitive to the high temperatures generated by other methods. Waterjet cutting is used in various industries, including mining andaerospace, for cutting, shaping, and reaming.



While using high-pressure water for erosion dates back as far as the mid-1800s with hydraulic mining, it was not until the 1930s that narrow jets of water started to appear as an industrial cutting device. In 1933, the Paper Patents Company in Wisconsin developed a paper metering, cutting, and reeling machine that used a diagonally moving waterjet nozzle to cut a horizontally moving sheet of continuous paper. These early applications were at a low pressure and restricted to soft materials like paper.

Waterjet technology evolved in the post-war era as researchers around the world searched for new methods of efficient cutting systems. In 1956, Carl Johnson of Durox International in Luxembourg developed a method for cutting plastic shapes using a thin stream high-pressure waterjet, but those materials, like paper, were soft materials.[3] In 1958, Billie Schwacha of North American Aviation developed a system using ultra-high-pressure liquid to cut hard materials.[4] This system used a 100,000 psi (690 MPa) pump to deliver ahypersonic liquid jet that could cut high strength alloys such as PH15-7-MO stainless steel. Used as a honeycomb laminate on the Mach 3 North American XB-70 Valkyrie, this cutting method resulted in delaminating at high speed, requiring changes to the manufacturing process. While not effective for the XB-70 project, the concept was valid and further research continued to evolve waterjet cutting. In 1962, Philip Rice of Union Carbideexplored using a pulsing waterjet at up to 50,000 psi (345 MPa) to cut metals, stone, and other materials. Research by S.J. Leach and G.L. Walker in the mid-1960s expanded on traditional coal waterjet cutting to determine ideal nozzle shape for high-pressure waterjet cutting of stone, and Norman Franz in the late 1960s focused on waterjet cutting of soft materials by dissolving long chain polymers in the water to improve the cohesiveness of the jet stream. In the early 1970s, the desire to improve the durability of the waterjet nozzle led Ray Chadwick, Michael Kurko, and Joseph Corriveau of the Bendix Corporation to come up with the idea of using corundum crystal to form a waterjet orifice, while Norman Franz expanded on this and created a waterjet nozzle with an orifice as small as 0.002 inches (0.05 mm) that operated at pressures up to 70,000 psi (483 MPa). John Olsen, along with George Hurlburt and Louis Kapcsandy at Flow Research (later Flow Industries), further improved the commercial potential of the waterjet by showing that treating the water beforehand could increase the operational life of the nozzle.

Abrasive waterjet



The Evolution of the Abrasive Waterjet Nozzle

While cutting with water is possible for soft materials, the addition of an abrasive turned the waterjet into a modern machining tool for all materials. This began in 1935 when the idea of

adding an abrasive to the water stream was developed by Elmo Smith for the liquid abrasive blasting. Smith’s design was further refined by Leslie Tirrell of the Hydroblast Corporation

in 1937, resulting in a nozzle design that created a mix of high-pressure water and abrasive for the purpose of wet blasting. Producing a commercially viable abrasive waterjet nozzle for precision cutting came next by Dr. Mohamed Hashish who invented and led an engineering research team at Flow Industries to develop the modern abrasive waterjet cutting technology. Dr. Hashish, who also coined the new term "Abrasive Waterjet" AWJ, and his team continued to develop and improve the AWJ technology and its hardware for many applications which is now in over 50 industries worldwide. A most critical development was creating a durable mixing tube that could withstand the power of the high-pressure AWJ, and it was Boride Products (now Kennametal) development of their ROCTEC line of ceramic tungsten carbide composite tubes that significantly increased the operational life of the AWJ nozzle. Current work on AWJ nozzles is on micro abrasive waterjet so cutting with jets smaller than 0.015 inch in diameter can be commercialized.

Applications

Because the nature of the cutting stream can be easily modified the water jet can be used in nearly every industry; there are many different materials that the water jet can cut. Some of them have unique characteristics that require special attention when cutting.

Materials commonly cut with a water jet include rubber, foam, plastics, leather, composites, stone, tile, metals, food, paper and much more. Materials that cannot be cut with a water jet are tempered glass, diamonds and certain ceramics. Water is capable of cutting materials over eighteen inches (45 cm) thick.

Important Questions and Answers: CNC Machines

***CNC MACHINES***

**1. Define numeraical control machine**

Numerical control machine cane be defined as a form of programmable machine in which the process are controlled by a program of numbers, letters, and symbols.

**2. What is NC part programming?**

NC part programming is the step by procedure of by which the sequence of processing steps to be performed on the NC machine is controlled by a program of numbers, letters, and symbols.

**3. What is APT language?**

APT [automated programming language]is a computer program, it automatically calculates the tool path, generates program and controls the machine by receiving general high level languages.

**4. Mention any 4 post processor statement in APT.**

COOLNT END FEDRAT/

**MACHIN/**

RAPID

**5. What is CNC?**

CNC is system consists of a computer, controller and a NC machine tool. Computer is used to store and edit the program. Controller controls the tool path based on the program.

**6. What is meant by machining centre?**

The machining centre is CNC system with automatic tool changing arrangement that is designed to perform a verity of machining operations, with large number of cutting tools.

**7. What is part program?**

Part program is a high level language containing the instructions for machining a part to various standard words, codes and symbols.

**8. What is post processing?**

Post processing is a computer program that takes a generalized part program output and adopts it to a particular machine control unit and machine tool combination. It is the basic intelligence required to change the program into computer language.

**9. Write the order of instructions in a part program.**

End of Preparatory function   Feed function       Tool function       block

**10. What is manual part programming?**

Manual part programming is a process of writing programs which consists of a set of instructions [contains codes, symbols and numbers] to carry out the machining of the work.

**11. What is preparatory function?**

It is word address format represented by the letter G, Followed by a numerical code for the operation of the control unit to instruct the machine tool.

**12. What is canned cycle?**

Canned cycle simplifies and shortens the programming in such way whenever any one of the operation is required.

**13.What are the major areas to be considered in the design of NC machine tools?**

i.Machine structure and frame ii.Location of transducer iii.Slideways

iv.Elements of transmission and positioning of sliders

v.Spindlesvi.Tool holding arrangements

**14.How the heat effect on the machine bed, tool holder can be taken care?**

i.Providing correctly designed mild steel structure with higher

stiffness ii.Use of ribs, braces, angle plates to increase stiffness

iii.Normal weight distribution over the entire frame

iv.The hollow cross section for beds, bases and columns with a number of ribs welded with the walls cater for the rigidity as well as opening for inspection, lubrication and collection of chip coolants.

v.Thermo symmetrical   design   of   all   parts.

vi.Providing large heat removing surfaces vii.Use

of excellent coolants

viii.Avoiding direct as well as local sources of heat such as sunlight and electrical motors.oil pumps respectively.

ix.Reduction of ambient temperature by using air conditioning units

x.Proper alignment of the machine elements relative to each other while in operation as well as in stationary conditions

**15.Explain Slide and Slideways**

In general machine tools are provided with tables, slides, carriages etc., to carry the work pieces or cutting tools etc., These parts are sliding in nature and mounted on the ways that are fixed on the other parts (column, housing, bed or knee) of the machines known as sliding ways.

**16. Explain the term “stick-up”**

Conventional sliders operating under sliding friction do not have a constant coefficient of friction and the highest value of co-efficient tends to be at the lowest rates of slide velocity.

This phenomenon given to the familiar “stricking” of oil lubricated slideing surfaces when

the fine adjustment is needed, a jerky action when movement takes place at low velocities.

The term “stick-slip” is used to describe these situations.